Available online at www.sciencedirect.com
ScienceDirect
Procedia Computer Science 98 (2016) 48 – 55
Procedia Computer Science

The 7th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN 2016)

Performance of GPSR and AOMDV in WSNs with Uncontrolled Mobility

Hosam Rowaihy*, Ahmed BinSahaq

Department of Computer Engineering

King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia

Abstract

Emergence and evolution of Wireless Sensor Networks (WSNs) opened the door for the development of many applications. Mobile Wireless Sensors Networks (MWSNs) is a subclass of WSNs in which some or all sensors are mobile. Although such mobility has benefits for extending network coverage, the existence of nodes mobility imposes challenges in the data delivery process as connectivity changes dynamically. This issue is exacerbated when nodes move in uncontrollable manner, e.g. mounted on helmets of factory workers or on vehicles. Existing WSNs routing protocols are mainly designed to support static or semi-dynamic scenarios. Due to the similarity between MWSNs and Mobile Ad-hoc Networks (MANETs), existing MANET routing protocols can be used for this purpose. In this paper, we use *ns2* to evaluate the performance of two MANET routing protocols, GPSR and AOMDV, in the field of MWSNs with a location-based sensing application assuming the nodes move in an uncontrollable manner. We use metrics such as packet delivery ratio, routing overhead, hop count, and energy consumption to test protocols performance. We also use a utility function to estimate the performance of the application. We find that the geographic-based routing, GPSR, works better than AOMDV due to its lower routing protocol overhead.

Peer-review under responsibility of the Program Chairs

Keywords: Mobile Wireless Sensor Networks; MWSNs; MANET; Uncontrollable Mobility; Routing protocols; Performance evaluation.

1. Introduction

Wireless sensor networks (WSNs) consist of low powered devices that have computation, wireless communication, and environment sensing capabilities. WSNs, usually consist of static sensors that monitor their surrounding environment and report their measurement to a data deposit node called sink or base-station node[1], possibly through multiple hops. In some WSNs, some of the network nodes have the ability to move from a location to another. For example, Robomote[2] is a mobile platform designed with two motors and can carry a mote or sensor device. The motion of Robomote is controlled by mote device (e.g. MICA mote) which can be programmed by the user. Similar to Robomote, a wheel-based robotic sensor node called RacemoteZ[3] is designed to monitor microclimate changes in

* Corresponding author. Tel.: +966-13-860-4505
E-mail address: rowaihy@kfupm.edu.sa

1877-0509
Peer-review under responsibility of the Program Chairs
doi:10.1016/j.procs.2016.09.010

dangerous environments that are inaccessible by humans or large robots. Building and deploying robots, however, can be expensive and time-consuming which is why in some applications sensors can be attached to moving objects that already exist in an environment such as buses or cars. For example, OpenSense[4,5] deploys sensors on top of moving buses and trams through the city of Zurich, Switzerland to gather data about air quality. Measurements of emitted gases (e.g. Ozone O_3, nitrogen dioxide NO_2, nitrogen monoxide NO and sulfur dioxide SO_2) in the city air are collected and analyzed. Many other environmental monitoring systems use mobile sensor networks such in[6,7,8] and[9]. The existence of nodes mobility in wireless sensor network may have some advantages such as extending network coverage[10] when nodes fail due to hardware faults or energy shortage. Also, sensing coverage can be extended to places where deployment of static or stationary sensors is impossible due to short time needed or deployment costs.

The existence of node mobility in WSNs introduces a subclass of sensor networks called Mobile Wireless Sensor Networks (MWSNs)[11]. In this paper, we focus on MWSNs in which sensor nodes are uncontrolled similar to OpenSense[5] system. The existence of uncontrolled mobility in MWSNs imposes many challenges in data delivery. Connectivity between sensor nodes is dynamically changing due to nodes mobility which affects data delivery to the base-station. Authors in[12] analyzed the effect of using controlled mobile sink nodes and uncontrolled mobile data MULEs on the performance of WSNs (static sensors) which is different than in our case as we consider uncontrolled mobile nodes and fixed sink. There are many routing protocols are developed for wireless sensor networks; most of them, however, are designed with the assumption that network sensors are static or semi-dynamic[13].

Mobile sensing systems such as OpenSense[4,5] and many others (e.g.[6,7,8]) either assume or use direct communication (Cellular/3G) for data delivery which is not always possible due to limited network coverage and capacity of sensor's battery. Instead, sensors in mobile wireless sensor network can form an ad-hoc network between them for forwarding packets to base-station. Due to the similarity between MANET (Mobile Adhoc NETwork)[14] and MWSNs, existing MANET routing protocols can be used for this purpose since they are designed to work in fully mobile ad-hoc networks. The nature of network communication in MWSNs (many to one), however, differs from MANETs (peer to peer). Also, MWSNs have higher node density with resources that are more constrained compared to MANETs. Theses issues make it more challenging to use MANET routing protocol in MWSNs.

In this paper, we study two different MANET routing protocols, Greedy Perimeter Stateless Routing (GPSR)[15] and Ad-hoc On-demand Multipath Distance Vector (AOMDV)[16] in MWSNs. These protocols represent two different categories of routing methods; the former is geographic-based while the latter is based on route discovery. We have chosen these two protocols to see how these different routing approaches behave in the existence of uncontrolled mobility. We use extensive simulation based on the network simulator *ns2*[17] to study the protocols suitability to work with MWSNs and uncontrolled mobile nodes. We assume that the MWSN serves a location-based sensing application in which different locations in the network field need to be monitored or sensed (e.g. fire detection systems).

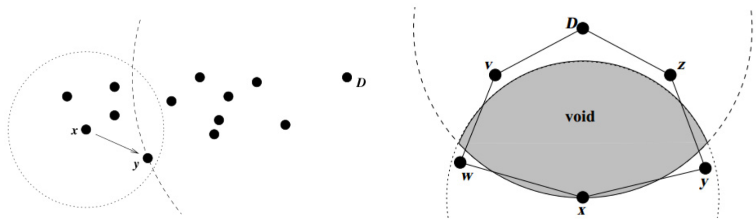
The remaining part of this paper is organized as following: Section 2 provides an overview of GPSR and AOMDV routing protocols and how they work. Section 3 discusses our network and application model. Section 4 shows our performance evaluation results. Finally, Section 5 concludes the paper.

2. MANET Routing Protocols

In this section we provide an overview of the two protocols that we use in our study, GPSR[15] and AOMDV[16].

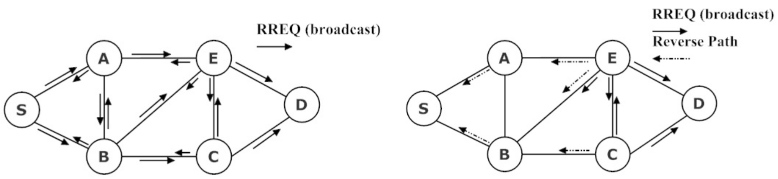
2.1. Greedy Perimeter Stateless Routing (GPSR)

GPSR[15] is a location-based routing protocol which assumes that each node knows its geographic location (e.g. using GPS). Each node announces its existence by broadcasting periodic beacons to its one-hop neighbors which contain the node's ID and its geographic location. As in Fig. 1a, GPSR greedily forwards a packet from the source node (**x**) to the closest next hop (**y**) to the destination node (**D**). Sometimes greedy forwarding becomes impossible as in Fig. 1b in which case no neighbor node is closer to destination **D** than **x** itself. In this case, GPSR tries to go around the void area using perimeter nodes (**w** then **v** or **y** then **z**) as in Fig. 1b. The packet follows a path formed by perimeter forwarding. Whenever it is possible, the packet is forwarded according to greedy forwarding again. Besides knowledge of its location, each source node in GPSR needs to know locations of its one-hop neighbors and the destination node (the base-station in our case).



(a) GPSR greedy forwarding (b) GPSR greedy forwarding fails

Fig. 1: The GPSR routing protocol [15].



(a) RREQ messages broadcast. (b) Reverse path formation.

Fig. 2: The AOMDV route discovery.

2.2. *Ad-hoc On-demand Multipath Distance Vector (AOMDV)*

AOMDV [16] is built based on AODV [18] routing protocol that uses a route discovery procedure. Source node floods the network with a Route Request (RREQ) messages to the destination marked with a unique sequence number. Intermediate nodes broadcast this request message unless it has a valid and fresh route to the destination, then it sends a Route Reply (RREP) message to the source node. Duplicate RREQ messages are discarded by intermediate nodes. When the first RREQ message reaches destination node, it sends back a RREP message toward source node following the reverse path formed by intermediate nodes during the discovery process. Destination discards any received duplicate RREQ messages (see Fig. 2a). The problem with AODV, it builds a single route path towards the destination. When this route fails, another route discovery is needed. AOMDV is designed to set up multiple routes to the destination with the same route discovery process (see Fig. 2b). AOMDV exploits the duplicate RREQ messages to build multiple paths within the source and intermediate nodes. Destination node sends RREP message to each RREQ message received from a different hop. AOMDV uses HELLO messages to detects links break.

3. Network Model

We assume that the network application is designed for an event detection such as chemical leakage or fire detection in specific locations. The mobile wireless sensor network consists of a set $N\{S_1, S_2, S_3, ..., S_n\}$ of randomly moving sensors. Main application is divided into set $J\{M_1, M_2, M_3, ..., M_J\}$ of location-based missions or points of interest. A mission represents a data request to collect sensing measurements from a specific location by all surrounding sensors. These requests can be changed based on new user requirements. Collected measurements are transferred to base-station. The number and locations of missions are user parameters. Every sensor in the network moves randomly according to its host object's behavior in an uncontrolled fashion. It also senses missions within a specific sensing range and sends measurements to the base-station. When data is received, it is analyzed by the application. The utility provided by a mobile sensor to a specific mission represents the probability of an event being detected by the sensor at that location. In most cases, this utility is affected by sensor type and the distance between that sensor and the event location. For instance, measurements taken by sensors near a gas leakage will be more accurate compared to

Table 1: Waspmote sensor node characteristics

Parameters	Values
Sensors	Temperature, CO Atmospheric Pressure
Sensing range	40 meters
Sensing energy consumption	12 mA (5V)
Communication range	80 meters
Wi-Fi Data Rate	2 Mbps
Wi-Fi TX/RX energy consumption	38 mA (4.2V)

Table 2: Simulation parameters

Parameters	Values
Mobility model	Random WayPoint
Simulation area	(400 X 400) m^2
Number of nodes	10, 50, 100, 150, 200
Number of base-station	1 (center/corner of the field)
Number of missions	30
Max Pause time	20 seconds
(Min, Max) node speed	(0.5,10) meter/s

measurements taken by sensors located farther. At each time unit, a single mission, M_j, may receive utility from one or more sensors. The utility received by M_j which we denote as u_j is defined as follows:

$$u_j = 1 - \prod_{S_i \to M_j} \left(1 - e_{ij}\right) \tag{1}$$

where e_{ij} is the utility contributed by sensor S_i to mission M_j which represents the event detection probability at mission's location. u_j is, hence, equal to the probability that the event is detected as the mission location. The main network goal is to maximize the average utility received by each mission or what we call network utility and denote as U. Hence, U is defined as follows:

$$U = (\sum_{j=1}^{J} u_j)/|J| \tag{2}$$

where u_j is the utility received by mission M_j (see equation 1) and $|J|$ is the size of set J which includes all missions. In this model, the system's performance depends on the amount of utility received by each mission and the number of missions that have been covered.

Many exiting mobile sensing systems assume unlimited direct wireless connection in which sensors use Cellular/3G connections to send data to back-end servers[4,5,6,8,7]. Other systems such as VSN (Vehicular Sensor Network)[9] uses opportunistic connectivity through Wi-Fi access points. In our model, mobile sensor nodes use the ad-hoc network formed between them to deliver data. In addition to its main role for environment sensing, each mobile sensor node plays a routing role to deliver packets to the base-station node. We assume that each mobile sensor knows its geographic location and locations of missions to be sensed. Sensors are omnidirectional, i.e. they can sense and measure multiple directions at the same time. For example, gas sensors can sense all the surrounding environment at once. Therefore, utility contributed by a single sensor can be used by all missions within its sensing range.

4. Performance Evaluation

In this section we evaluate the performance of both GPSR and AOMDV protocols for WSNs with mobile nodes that move in an uncontrollable manner.

4.1. Simulation Setup

We model sensor nodes in our system based on *Waspmote*[20] sensor platform (Waspmote is Libelium's advanced mote for WSNs). We assume that sensor board consists of three sensors, Temperature, Carbon Monoxide (CO) and Atmospheric Pressure Sensor[20] as these sensors can be used for fire detection. We use similar specifications of these sensors such as the size of generated data and the energy consumption. We assume that each sensor node is also equipped with a Wi-Fi communication module for ad-hoc communication. Table 1 contains characteristics that we model sensor node based on. We use the *ns2* simulator[17] to evaluate the network performance. For sensors mobility, we use the *Bonnomotion* tool[21]. Table 2 contains the simulation parameters.

As mentioned in Section 3, all missions are modeled as event detection tasks such as chemical leakage or fire detection. The utility function we use to model the utility provided by sensor S_i to mission M_j is defined as follows:

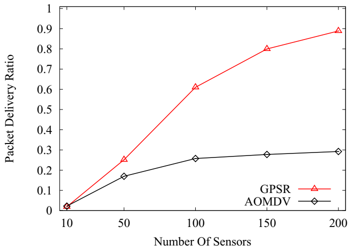
$$e_{ij} = exp\left(log\left(P_{FA}\right)\left(1 + \frac{SNR_1}{D_{ij}^2}\right)^{-1}\right) \tag{3}$$

where P_{FA} is the false alarm probability (user chosen parameter) and SNR_1 is the signal to noise ratio at a distance of one meter from the source signal. Utility e_{ij} represents the probability of event detection by sensor S_i to mission M_j. D_{ij} is the distance between sensor S_i and mission M_j at sensing time. We use the same utility function used in[22]. Other functions can be used as well. Missions are uniformly distributed within (400 X 400) m^2 field. Sensors move randomly in the field according to Random Way Point (RWP) model[23]. While moving and based on its sensing rate (every 5 seconds), sensors evaluate the expected utility value, e_{ij}, for surrounding missions as in equation 3. Utility, e_{ij}, is set to zero when the distance, D_{ij} becomes greater than the sensing range. If there are one or more missions in the surrounding area, the sensor turns on its sensing module for one second to sense nearby mission(s). We set P_{FA} and SNR_1 to 0.001 and $30dB$ respectively. These values are used for testing purposes and may not exactly model the behavior of a particular sensor type.

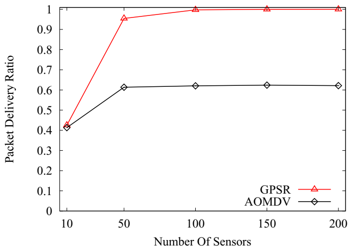
We run a set of experiments for evaluating GPSR and AOMDV routing protocols. We use a 1.5 second interval for both GPSR 's beacons and AOMDV 's HELLO messages. Obtained results are taken based on network lifetime of 1800 seconds and are averaged over 20 runs. In the following experiments runs, we vary node density from 10 to 200 nodes in the same sensing field. We place the base-station at both the center and one of the corners. We evaluate the routing protocols (both GPSR and AOMDV) performance according to five different metrics: packet delivery ratio, utility received by each mission, routing protocol overhead, hop count and the node energy consumption.

4.2. Packet Delivery Ratio

Fig. 3 shows the percentage of successfully delivered data packets to the base-station. We can see that both routing protocols perform similarly when only 10 nodes are used because the network is disconnected most of the time. When more nodes are deployed both protocols perform better since the probability of finding a path toward destination increases. GPSR performs better than AOMDV routing protocol because it works in a proactive fashion. AOMDV, on the other hand, consumes a lot of time and bandwidth in finding a path towards the destination. As expected, the location of base-station plays a major role in data delivery. When the base-station is positioned at the corner of the field, both protocols perform badly when low node density is used (see Fig. 3a). The farther the base-station is located, the higher the possibility that packets are dropped by intermediate nodes because there is no valid path to the destination. GPSR performs better than AOMDV when more nodes are deployed. GPSR has the advantage of leveraging the higher node density because the source node uses geographic information to find the path to the destination node. When the base-station is positioned at the center, almost all packets are delivered when more than 100 nodes are deployed, (see Fig. 3b). AOMDV gets saturated when the network density is increased. In the worst case, i.e. when base-station is at the corner, only about 20-30% of sent packets are delivered (Fig. 3a), and in the best case, i.e. when base-station is at the center of the field, almost 60% of sent packets are delivered (Fig. 3b). To study why AOMDV gets saturated at 60% we plotted the packet loss ratio (PLR) and how routing and MAC layer failures impact it. Both Routing and MAC failures are plotted as ratios from lost packets, i.e. we only consider the packets that were lost. MAC failure happens when packets are dropped because the MAC layer could not send a packet to the next hop either because it has already left the communication range or because of collision. Routing failure happens when the node could not find a valid route towards the destination. We plotted the same ratios for GPSR for comparison (Figs. 4 and 5). We notice that when node density is low, most of the packets are dropped due to routing failure. This is clear when the base-station is positioned at the corner of the field. In this case, the base-station and network nodes are disconnected most of the time. In AOMDV, most of the packets are dropped because of MAC failure. This happens due to the high number of collisions especially when node density is increased (more than 50 nodes) due to the high number of sent routing control packets during the route discovery and maintenance process. In GPSR, the effect of MAC failure is limited since GPSR only sends one-hop beacons and it uses sent data packets as implicit beacons. Most of the dropped packets in GPSR are due to routing failure which is acceptable since GPSR depends on beacons to build neighbors list that is used to make routing decisions.

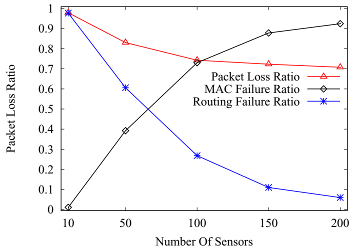


(a) Base-station at the corner

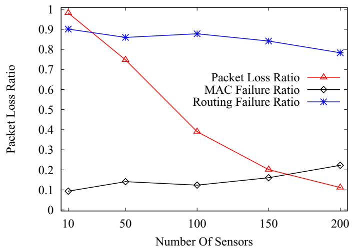


(b) Base-station at the center

Fig. 3: Packet Delivery Ratio.

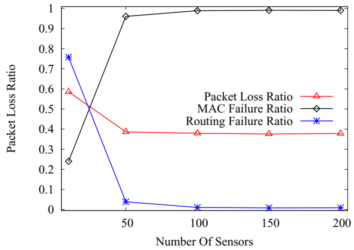


(a) AOMDV

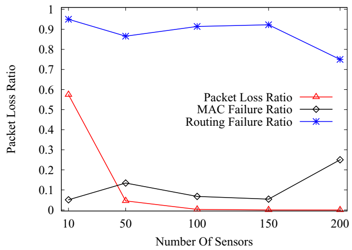


(b) GPSR

Fig. 4: Packet Loss Ratio, base-station is positioned at the corner of the field.



(a) AOMDV



(b) GPSR

Fig. 5: Packet Loss Ratio, base-station is positioned at the center of the field.

4.3. Received Utility

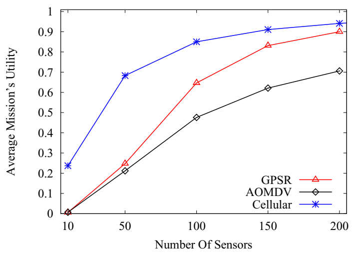
Each network mission receives utility based on measurements taken by the mobile sensors. We use this metric to see effect of both the underlying data delivery mechanism (routing protocol) and the uncontrolled mobility on application performance. For comparison, we allow sensor nodes to send data packets directly using Cellular connection (as used in [5,7] and [8]). Fig. 6 shows the average utility received by each mission during the network lifetime. As expected, higher node density improves application performance since more missions are covered when more sensors are deployed. The effect of packet delivery ratio (see Fig. 3 and Fig. 6) is reflected on the application performance. GPSR outperforms AOMDV when higher node density is used due to its higher packet delivery ratio. When the base-station is at the center, GPSR behaves similar to Cellular connection when more than 50 sensors are used.

4.4. Routing Overhead

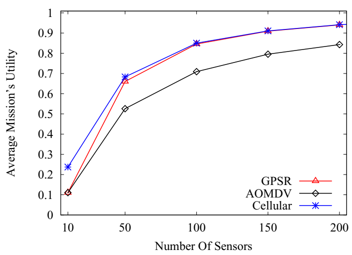
Fig. 7 shows the routing protocol overhead defined as the total number of sent routing packets during the network lifetime. As expected, AOMDV produces much higher overhead compared to GPSR due to the route discovery process. Also, AOMDV uses HELLO messages for broken link detection which increases the protocol overhead. GPSR uses only location information for packet forwardingAlso, GPSR allows the routing protocol to exploit sent packets as implicit beacons which reduces the need to send more beacons. The location of the base-station affects the performance of both routing protocols. When the base-station is at the corner of the field, both protocols need to forward more packets. AOMDV is drastically affected by location of base-station since all sensors want to send packets to base-station which initialize a route discovery process by all network nodes. We can see this effect when node density is increased (see Fig. 7a). When the base-station is at the center of the field, distance between data sources and the destination is smaller and paths are formed faster and with less overhead (see Fig. 7b).

4.5. Hop Count

Fig. 8 shows the average hop count that received packets traverse before they reach the base-station. We only consider number of hops between source node and destination as it reflects the path length and the ability of the routing protocol to find the shortest path. As expected, the farther the base-station is positioned, the longer the path

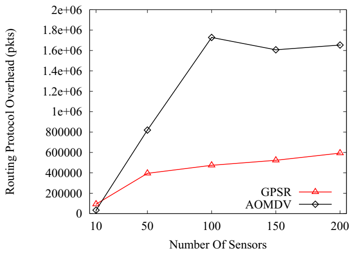


(a) Base-station at the corner

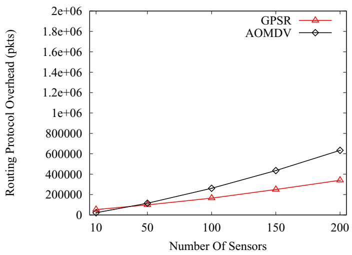


(b) Base-station at the center

Fig. 6: Average Mission's Utility, 30 missions

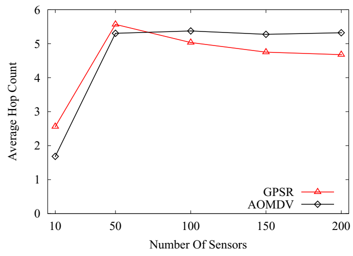


(a) Base-station at the corner

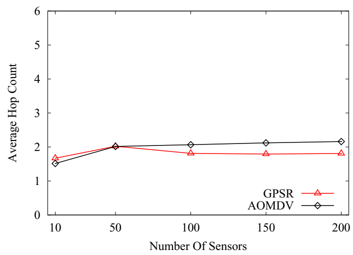


(b) Base-station at the center

Fig. 7: Routing protocol overhead. All routing packets sent network wide



(a) Base-station at the corner



(b) Base-station at the center

Fig. 8: Average hop count traversed by packet before it reaches destination

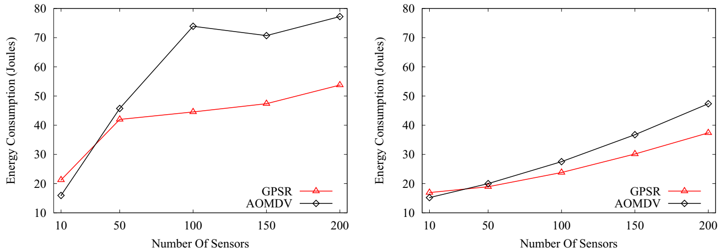
packets follow before they are successfully delivered (see Fig. 8a and Fig. 8b). In GPSR, we can see that packets, when node density is low (10 nodes), follow a longer path than AOMDV. This is because when greedy forwarding fails, GPSR tries to forward the packets around void areas using perimeter mode. This means that packets traverse along more nodes with the hope to find the destination. When more nodes are deployed, GPSR chooses to forward packets to the closest hop to destination (i.e. more neighbors). This is reflected on the path length used by GPSR as it becomes shorter than AOMDV's which uses existing route unless it fails, then it tries to use an alternative one.

4.6. Energy Consumption

Fig. 9 shows the average energy consumed by each sensor during the network lifetime. Sensors consume energy for both sensing and communication. We can see that AOMDV consumes more energy compared to GPSR. This is due to the high routing overhead during the route discovery process (see Fig. 7). In addition to route discovery, AOMDV uses periodic HELLO messages for link failure detection. This becomes clear when number of nodes is increased in which case each node initiates its own route discovery process. GPSR consumes more energy than AOMDV when only 10 nodes are used. This due the nature of the GPSR protocol as when greedy forwarding fails, GPSR tries to forward packets along perimeter until packet is received or dropped with no destination found. As we discussed earlier, the position of the base-station plays a major role in consumed energy. Source nodes in AOMDV need to search longer for the destination when the base-station is positioned at the corner of the field. Also, the path towards the destination becomes longer (see Fig. 8) for both protocols which is reflected on energy consumption.

5. Conclusion

In this paper we evaluated the performance of two different MANET routing approaches, namely GPSR and AOMDV, in a wireless sensor network with uncontrolled mobile nodes. AOMDV is not well suited to work in MWSNs; even with its ability to handle link breakage caused by node mobility (e.g. using multiple path routing), the nature of the traffic in MWSNs (all to one) produces high routing overhead due to the route discovery process. This results in high energy consumption. GPSR performs better especially when the network density is large enough. However, its dependency on geographic information may be a drawback especially when used in sensitive applications (e.g military missions) that require preserving location privacy. In general, GPSR performs better that AOMDV due



(a) Base-station at the corner (b) Base-station at the center

Fig. 9: Average node energy consumption during whole network lifetime

to its advantage of using geographic information that eliminate its needs for route discovery process used by AOMDV.

References

1. Akyildiz, I.F., Su, W., Sankarasubramaniam, Y. and Cayirci, E., 2002. Wireless sensor networks: a survey. Computer networks, 38(4), pp.393-422.
2. Dantu, K., Rahimi, M., Shah, H., Babel, S., Dhariwal, A. and Sukhatme, G.S., 2005, April. Robomote: enabling mobility in sensor networks. In Proceedings of the 4th international symposium on Information processing in sensor networks (p. 55). IEEE Press.
3. Song, G., Zhou, Y., Ding, F. and Song, A., 2008. A mobile sensor network system for monitoring of unfriendly environments. Sensors, 8(11), pp.7259-7274.
4. Aberer, K., Sathe, S., Chakraborty, D., Martinoli, A., Barrenetxea, G., Faltings, B. and Thiele, L., 2010, November. OpenSense: open community driven sensing of environment. In Proceedings of the ACM SIGSPATIAL International Workshop on GeoStreaming (pp. 39-42).
5. Li, J.J., Faltings, B., Saukh, O., Hasenfratz, D. and Beutel, J., 2012. Sensing the air we breathe-the opensense zurich dataset. In Proceedings of the National Conference on Artificial Intelligence (Vol. 1, No. EPFL-CONF-197502, pp. 323-325).
6. Hasenfratz, D., Saukh, O., Sturzenegger, S. and Thiele, L., 2012. Participatory air pollution monitoring using smartphones. Mobile Sensing, pp.1-5.
7. Devarakonda, S., Sevusu, P., Liu, H., Liu, R., Iftode, L. and Nath, B., 2013, August. Real-time air quality monitoring through mobile sensing in metropolitan areas. In Proceedings of the 2nd ACM SIGKDD International Workshop on Urban Computing (p. 15). ACM.
8. Al-Ali, A.R., Zualkernan, I. and Aloul, F., 2010. A mobile GPRS-sensors array for air pollution monitoring. Sensors Journal, IEEE, 10(10), pp.1666-1671.
9. Re, G.L., Peri, D. and Vassallo, S.D., 2014. Urban air quality monitoring using vehicular sensor networks. In Advances onto the Internet of Things (pp. 311-323). Springer International Publishing.
10. Liu, B., Brass, P., Dousse, O., Nain, P. and Towsley, D., 2005, May. Mobility improves coverage of sensor networks. In Proceedings of the 6th ACM international symposium on Mobile ad hoc networking and computing (pp. 300-308). ACM.
11. Rezazadeh, J., 2012. Mobile wireles sensor networks overview. International Journal of Computer Communications and Networks (IJCCN).
12. Basagni, S., Carosi, A. and Petrioli, C., 2007, September. Controlled vs. uncontrolled mobility in wireless sensor networks: Some performance insights. In Vehicular Technology Conference, 2007. VTC-2007 Fall. 2007 IEEE 66th (pp. 269-273). IEEE.
13. Akkaya, K. and Younis, M., 2005. A survey on routing protocols for wireless sensor networks. Ad hoc networks, 3(3), pp.325-349.
14. Bansal, M., Rajput, R. and Gupta, G., 1999. Mobile ad hoc networking (MANET): Routing protocol performance issues and evaluation considerations. The internet society.
15. Karp, B. and Kung, H.T., 2000, August. GPSR: Greedy perimeter stateless routing for wireless networks. In Proceedings of the 6th annual international conference on Mobile computing and networking (pp. 243-254). ACM.
16. Marina, M.K. and Das, S.R., 2006. Ad hoc ondemand multipath distance vector routing. Wireless Communications and Mobile Computing, 6(7), pp.969-988.
17. Network simulator2, `http://www.isi.edu/nsnam/ns/`
18. Perkins, C.E.; Royer, E.M., "Ad-hoc on-demand distance vector routing," in Mobile Computing Systems and Applications, 1999. Proceedings. WMCSA '99. Second IEEE Workshop on , vol., no., pp.90-100, 25-26 Feb 1999.
19. Rowaihy, H., Johnson, M., Bar-Noy, A., Brown, T. and Porta, T.L., 2008, November. Assigning sensors to competing missions. In Global Telecommunications Conference, 2008. IEEE GLOBECOM 2008. IEEE (pp. 1-6). IEEE.
20. Libelium waspmote, `http://www.libelium.com/development/waspmote`
21. BonnMotion, Mobility scenario generation tool, `http://sys.cs.uos.de/bonnmotion/`
22. Rowaihy, H., Johnson, M.P., Pizzocaro, D., Bar-Noy, A., Kaplan, L., La Porta, T. and Preece, A., 2009. Detection and localization sensor assignment with exact and fuzzy locations. In Distributed Computing in Sensor Systems (pp. 28-43). Springer Berlin Heidelberg.
23. Camp, T., Boleng, J. and Davies, V., 2002. A survey of mobility models for ad hoc network research. Wireless communications and mobile computing, 2(5), pp.483-502.